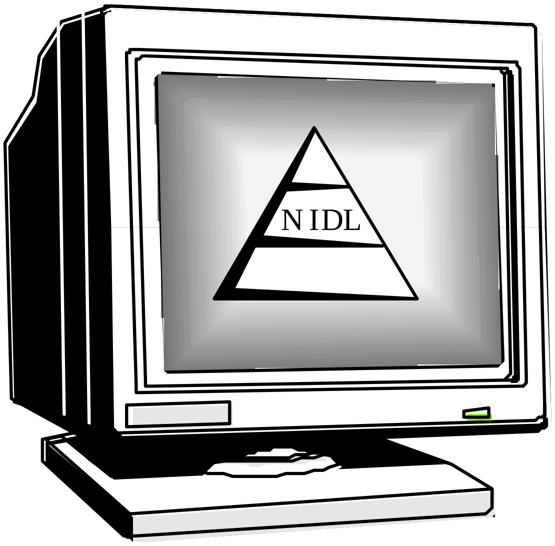

The Siemens SCM21130LS 21 inch color monitor (18.7" viewable area, selling price $2800--volume pricing can be quoted) has very good image quality and features that make it an excellent candidate display device for NIMA Imagery Exploitation Capability workstations. Based on our evaluation, NIDL certifies the Siemens SCM21130LS color monitor as being suitable for IEC workstations for the Image Analyst and Cartographer applications. NIDL rates this color monitor as a “B” for both monoscopic and stereo modes. It has built-in circuitry to maintain very stable luminance settings and color temperature over its lifetime. In a light ambient, the monitor is calculated to achieve 158:1 dynamic range with 3 fc illumination, and 60:1 with 10 fc illumination falling onto the screen. Based on field experience, Siemens calculates the reliability of its grayscale version of this monitor as 65,000 hours MTBF.

Evaluation of the Siemens SCM21130LS 4 x 3 Aspect Ratio, 21-Inch Diagonal Color CRT Monitor

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NIDL IEC Monitor Certification Report

The Siemens SCM21130LS Color CRT Monitor

FINAL GRADES
Monoscopic Mode: B
Stereoscopic Mode: B

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way

The Siemens SCM21130LS 21 inch color monitor (18.7" viewable area, selling price $2800--volume pricing can be quoted) has very good image quality and features that make it an excellent candidate display device for NIMA Imagery Exploitation Capability workstations. Based on our evaluation, NIDL certifies the Siemens SCM21130LS color monitor as being suitable for IEC workstations for the Image Analyst and Cartographer applications. NIDL rates this color monitor as a "B" for both monoscopic and stereo modes. It has built-in circuitry to maintain very stable luminance settings and color temperature over its lifetime. In a light ambient, the monitor is calculated to achieve 158:1 dynamic range with 3 fc illumination, and 60:1 with 10 fc illumination falling onto the screen. Based on field experience, Siemens calculates the reliability of its grayscale version of this monitor as 65,000 hours MTBF.

The monitor meets all IEC requirements in the monoscopic mode except for a value of 3.91± 0.3% for halation which somewhat exceeds the maximum of 3.5% allowed by the IEC specification, and the warm-up time, which will be fixed in a firmware update. The Siemens SCM21130LS passes all the important criteria of the IEC specification in the stereo mode. The exception is the maximum luminance in stereo for a full white screen value of 5.65 fL, instead of a value of 6 fL min± 4% (or 5.76 to 6.24 fL). For a smaller white area, the current limiting circuits are not in play and a value of close to 9 fL is observed in the Siemens color monitor. The refresh rate of 60.5 Hz per eye exceeds the IEC spec of 60 Hz per eye. The stereo extinction ratio of 18.1:1 exceeds the IEC specification determined with StereoGraphics CrystalEyes shutter glasses of 15:1. With a StereoGraphics Zscreen and passive glasses the extinction ratio averages 11.2:1. Stereo performance is important because this monitor is being considered for an application that employs full time stereo color operation in the IEC workstation. It should be noted that the maximum horizontal scan rate is 135 kHz, which is enough higher than other COTS color monitors so that it can achieve the 60 Hz per eye in stereo operation. The timing formats preset in the monitor (19 possible) must be established to correspond to the video display driver card for optimum monoscopic and stereo performance.

The Siemens SCM21130LS features a CRT having a 0.22mm horizontal dot screen with a dispenser cathode, an INVAR mask, and an anti-static, anti-reflective coating on the viewing surface. The manufacturer lists the maximum addressability, for the monoscopic mode, as 1600 x 1200 pixels at 75 Hz. The 1600 pixels horizontal addressability is well within the limit of 1727 pixels maximum as defined by the phosphor pitch of 0.22mm horizontal and the horizontal viewable image size of 1380 mm. All internal functions and formats are accessed and modified via a RS232 serial port on the front of the monitor.

Siemens factory representatives have been very cooperative and forthcoming in their support of testing of their color monitor at NIDL. Experience with the grayscale version of this monitor at JICPAC has been very positive.

Siemens monitors are described on its website, http://www.ad.siemens.de/monitors

NIDL previously tested the Viewsonic P817 21 inch color CRT monitor and certified it with ratings of B in both the monoscopic and stereoscopic modes. The IEC Contractor has liked the price-performance of this monitor. For some reason, which the manufacturer would not divulge, Viewsonic no longer carries the $1600 P817 in its catalog. A comparison of a number of the IEC monitor specifications for the Viewsonic P817 and the Siemens 21130LS is given below. It should be noted that the IEC specification of 15 to 1 was based on the use of the IR wireless CrystalEyes shutter glasses. The Siemens monitor with its many features and reliable operation should offer a low total cost of ownership to the IEC program. Further product improvements are expected to be made that will increase its performance.

Monoscopic Mode	**IEC Requirement**	**Viewsonic P817**	**Siemens 21130LS**
Luminance (Lmax)	30 fL	32.8 fL	30.8 fL at 6500K
Uniformity (Lmax)	20%	17.8%	18.8%
Halation	3.5%	4.3%	3.91% ±0.3%
Reflectance	Not Specified	4.6%	5.5%
Cm, Zone A, 7.6 inch	25% minimum	29%	36%
Cm, Zone B	20% minimum	40%	21%
Linearity	1.0% ±0.6%	0.88%	1.59%
Warm-up time, Lmin to ± 10%	60minutes max	49 minutes	60 minutes
Stereoscopic Mode			
Lmax	6 fL	6.04 fL	5.65fL at 6500K
Refresh rate	60 Hz per eye	60 Hz	60.5 Hz
Extinction ratio	15:1 minimum using CrystalEyes	10.0:1 Zscreen	11.2:1 Zscreen 18.1:1 CrystalEyes
Price		$1600	<$2800

Color monitors are more difficult to evaluate and their performance may not compare to monochrome monitors. But, they do give the analyst the additional dimension of color for their tasks. Color monitors have three electron guns (R, G, and B) to focus and converge. They also have a perforated steel mask that separates the colors on the screen and this adds complexity. Color lines formed on the phosphor screen may not be as narrow as for a monochrome, single electron gun-formed spot. The color monitor's light output may not be as high. The IEC monitor specifications for color monitors reflect this difference, and are less stringent than for a monochrome monitor.

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1600 x 1200	pass
Dynamic Range	24.7dB	24.9 dB	pass
Luminance (Lmin)	0.1 fL min ± 4%	0.1 fL	pass
Luminance (Lmax)	30 fL ± 4%	30.8 fL at 6500K	pass
Uniformity (Lmax)	20% max.	18.8 %	pass
Halation	3.5% max.	3.91± 0.3%	fail
Color Temp	6500 to 9300 K	9036 K	pass
Reflectance	Not specified	5.5 %	
Bit Depth	8-bit± 5 counts	8-bit	pass
Step Response	No visible ringing	Clean	pass
Uniformity (Chromaticity)	0.010 Δu’v’max.	0.005 Δu’v’	pass
Pixel aspect ratio	Square, H = V± 6%	Set to square	pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	18.7 inches	pass
Cm, Zone A, 40% circle, 9.54 inch	25% min.	36 %	pass
Cm, Zone B	20% min.	21 %	pass
Pixel density	72 ppi min.	107 ppi	pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.9	pass
Straightness	0.5% max ± 0.02%	0.42%	pass
Linearity	1.0% max ± 0.6%	1.59 %	pass
Jitter	2 ± 2 mils max.	1.35 mils	pass
Swim, Drift	5 ± 2 mils max.	1.42/1.46 mils	pass
Warm-up time, Lmin to ±50%	30 mins. Max ± 0.5 minute	59 min.	fail+
Warm-up time, Lmin to ± 10%	60 mins. Max ± 0.5 minute	60 mins.	pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 73 Hz	pass
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 1024 (I)	pass
Lmin	Not specified	0.10 fL	
Lmax	6 fL min± 4%	5.65 fL at 6500K	fail
Dynamic range	17.7 dB min	17.5 dB	fail
Uniformity (Chromaticity)	0.02 Δu’v’max	0.008 Δu’v’	pass
Refresh rate	60 Hz per eye, min	60.5 Hz	pass
Extinction Ratio	15:1 min with CE	11.2: 1(Z) (CE=18.1:1)	(Z)fail; (CE) pass*
AMBIENT LIGHTING			
Dynamic Range 22 dB (158:1)	No specification	3 fc	
Dynamic Range17.8 dB (60:1)	No specification	10 fc	

(I)denotes interlaced scanning
+ monitor can be adjusted with firmware change to meet spec
(Z) denotes StereoGraphics ZScreen LCD shutter panel
(CE)* passes with StereoGraphics CrystalEyes 18.1:1

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Siemens SCM21130LS, color CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091*, *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC)*, August 25, 1999.

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*
  Publication No. 0201099-091, Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC), August 25, 1999.

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The Siemens SCM21130LS Color CRT Monitor

Siemens Specifications

The Siemens SCM-Series of high resolution digital color monitors is designed to meet the demanding requirements of Imaging and Mapping in stereo mode. The monitor features high resolution at high luminance with low background levels for a wide dynamic range. The monitor's internal microprocessor controls all electrical and magnetic monitor functions, and continuously adjusts drive levels to maintain constant luminance over the life of the CRT. For each format, the dynamic focus ensures optimal sharpness at any point on the screen. The monitor is capable of storing up to 19 different timing formats. All formats are stored internally, including a full set of screen settings for each. Formats are selected and modified through the RS 232 serial port. According to Siemens, the specifications for the Siemens SCM21130LS monitor are:

Specifications	**SCM21130LS**
Synchronization range	Horizontal: 70-135 kHz, Vertical: 50-130 Hz
Maximum resolution	1600 x 1200
Maximum refresh rates	
1280 x 1024 1600 x 1200	85 Hz 75 Hz
Video clock frequency	220 MHz
Timing presets	
User programmable	19
Signal cable	5 BNC
Input Signal, Video	0.70 Vp-p, Analog
Sync.	RGB with separate H- and V-SYNC RGB With CSYNC on H-SYNC line RGB with SYNC on green
Resolution, max	1600 dots x 1200 lines
Viewable image size	18.7 inches diagonal, 380 mm horiz, x 285 mm vert.
Color Temp (4 presets)	9300 K, 7500 K, 6500 K, User-defined
Temperature	5 deg to 40 deg C operation
Humidity	20% to 80% operation

Features

- CRT with anti-reflective and antistatic panel and dispenser cathode for long CRT life.
- Automatic calibration of color temperature without external sensor after power on every 30 seconds, after 20 minutes every hour
- Connection of triax cables (double shielded)
- Power down management (VESA DPMS)
- High resolution CRT, 35 fL (up to 120 cd / m^2), front of screen luminance through 51% total transmission.
- 1600 x 1280 addressability standard
- Scan range of 70 to 135 kHz horizontal and 50 to 130 Hz vertical
- Microprocessor control of all internal monitor functions

- Front panel brightness contrast and geometry controls are standard and can be disabled for calibrated applications
- Front panel control for image rotation
- Ambient light sensor for automatic contrast control

CRT: 21" (18.7" viewable image size) flat, square[1] CRT, 0.22mm horizontal dot pitch, dispenser cathode. Static and dynamic focus. Black matrix with Invar Shadow Mask. Anti-static, anti-reflective coating. P22 phosphor, medium-short persistence.

Front Panel Controls: Power (on/off), contrast, and brightness.
On-Screen Menu Controls: Power (on/off), contrast, brightness, linearity, H/V phase and amplitude, pin and barrel, image rotation, VESA DPMS (on/off), color temperature, trapezoid correction, user programmable timing presets and Moiré compensation. Also featured is an ambient light sensor for automatic contrast control.
Power supply: 94 to 264 V, 47 to 63.6 Hz. 150W (approx).
Size/weight: 19.6" W x 19.0" H x 20.5" D (59.4 lbs.).
Regulatory compliance:
Safety: UL1950, CSA C22.2 No 950, EN 60 950.
X-radiation: DHHS
EMC: IEC 601-1-2, FCC Class A
MPR II
Energy saving: VESA DPMS.
Miscellaneous: CE Mark, ISO 9001 certified plant

[1] *Flat, square is an industry standard term used since 1997 indicating minimal curvature of the monitor tube. This does not mean that the monitor is completely flat.*

I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- StereoGraphics ZScreen 19-inch LCD shutter with passive polarized eyeglasses.
- StereoGraphics CrystalEyes shutter glasses.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range measured in 1600 x 1200 format is 24.9 dB in a dark room. It is less than 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93}. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene icebox. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: DR=10log(Lmax/Lmin)

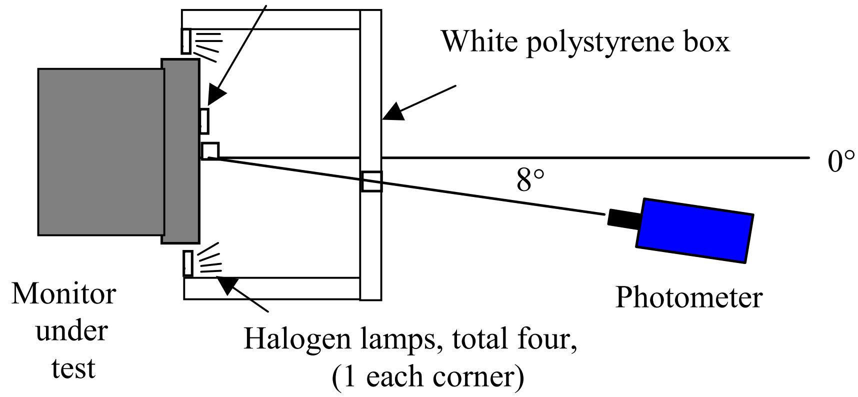


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate
VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	21.2 fc
Reflected Luminance	1.16 fL
Faceplate Reflectance	5.5 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 28.0 dB in a dark room to 22 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms
Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.1 fL.

Ambient Illumination	Dynamic Range
0 fc (Dark Room)	24.9 dB
1 fc	23.0 dB
2 fc	21.7 dB
3 fc	20.7 dB
4 fc	19.8 dB
5 fc	19.2 dB
6 fc	18.6 dB
7 fc	18.0 dB
8 fc	17.6 dB
9 fc	17.1 dB
10 fc	16.8 dB

II.2. Maximum Luminance (Lmax)

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

The highest luminance for Lmax was 30.8 fL measured at screen center in 1600 x 1200 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1600 x 1200	9036 K	0.288	0.291	30.8 fL

II.3. Luminance (Lmax) and Color Uniformity

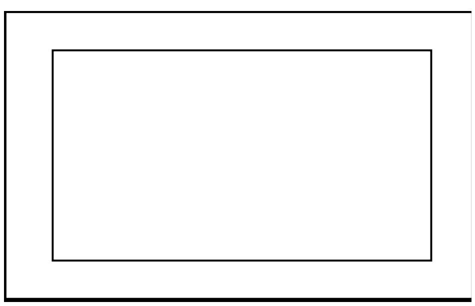
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 18.8 % across the screen. Chromaticity variations were less than 0.005 Δ u'v' units.

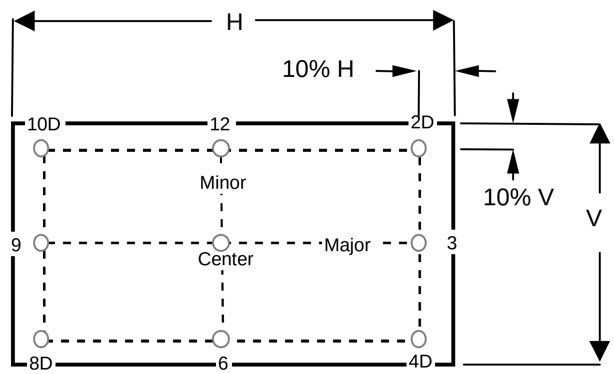
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of Δu′v′.

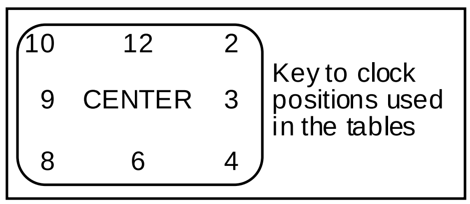
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1600 x 1200

POSITION	CCT	CIE x	CIE y	L, fL
center	9036	0.288	0.291	22.4[2]
2	9132	0.287	0.291	18.9
3	9118	0.288	0.289	18.5
4	9552	0.286	0.284	18.2
6	9502	0.286	0.285	19.4
8	9229	0.286	0.291	20.2
9	9187	0.286	0.292	20.5
10	9012	0.287	0.294	20.3
12	9425	0.284	0.291	20.5



1600 x 1200

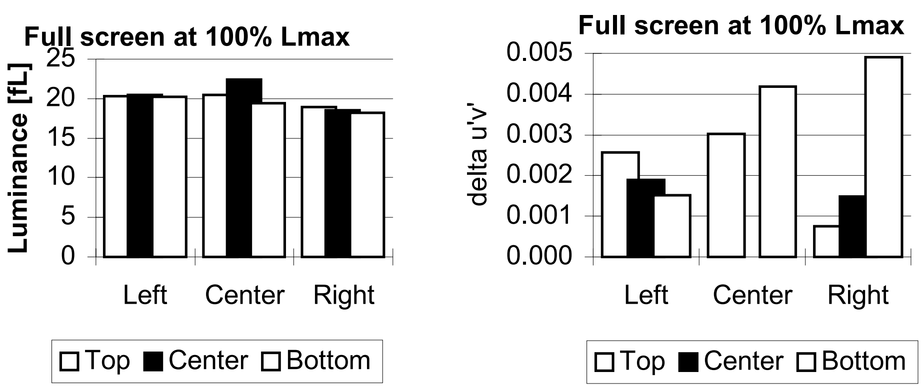


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity. Spatial luminance uniformity = (Lmax-Lmin)/Lmax. Delta u'v' of 0.004 is just visible.

[2] Re-measurement of Lmax at screen center 9-19-2000 is 30.8 fL at 6500K when monitor timing is optimized

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 3.91% ±0.3% on a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

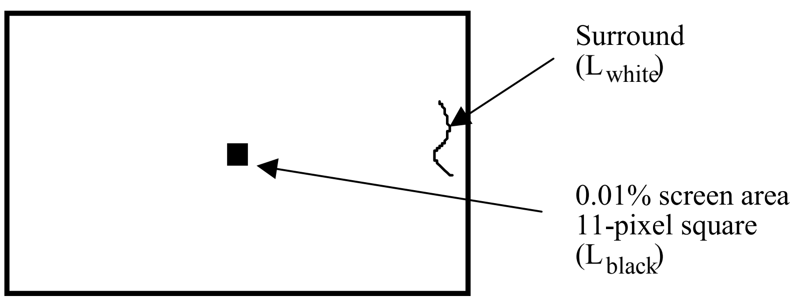


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer, which is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\%\ \text{Halation} = L_{black} \ / \ (L_{white} - L_{black}) \ \times 100$$

Where, L_{black} = measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white} = measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	0.8 fL ± 4%	0.77 fL to 0.83 fL
Lwhite	21.1 fL ± 4%	20.3 fL to 21.9 fL
Halation	**3.91% ± 0.3%**	**3.61% to 4.23%**

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of 9036K for the measured white point lies within 0.007 Δu'v' from the day light locus accepted by IEC (0.010 Δu'v' maximum is allowed).

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 Δu'v' of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute Δu'v' values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x, y) by the VESA/McCamy formula: CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517, where n = (x-0.3320)/(0.1858 - y). [This is on p. 227 of the FPDM standard]

2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second edition) to compute the point (xd,yd) associated with CCT.
   - First, define u = 1000/CCT.
   - If CCT < 7000, then xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u +
   - 0.244063.
   - If CCT > 7000, then xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u +
   - 0.237040.
   - In either case, yd = -3.000 xd^2 + 2.870 xd -0.275.

5. Convert (x,y) and (xd,yd) to u'v' coordinates:
   - (u',v') = (4x,9y)/(3 + 12y - 2x)
   - (u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)

6. Evaluate Δ-u'v' between (u,v) and (ud,vd):
   - delta-u'v' = sqrt[(u' - u'd)^2 + (v' - v'd)^2].

7. If Δ-u'v' is greater than 0.01, display fails the test. Otherwise it passes the test.

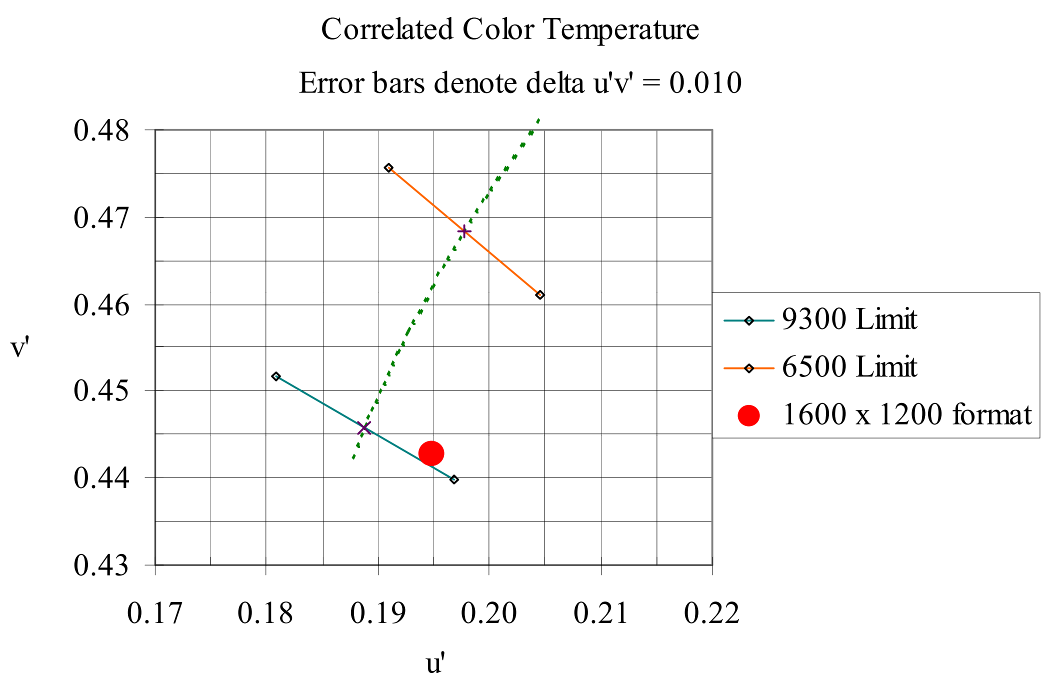


Figure II.5-1 *CCTs of measured whitepoints are within the boundaries required by IEC.*

Table II.5-1 Δu'v' Distances between measured whitepoints and CIE coordinate values from D_{65} to D_{93}.

	1600 x 1200
CIE x	0.288
CIE y	0.291
CIE u'	0.195
CIE v'	0.443
CCT	9036
delta u'v'	0.007

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Monotonic increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Neither black level clipping nor white level saturation was observed.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM F500to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM F500was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts.[3] The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

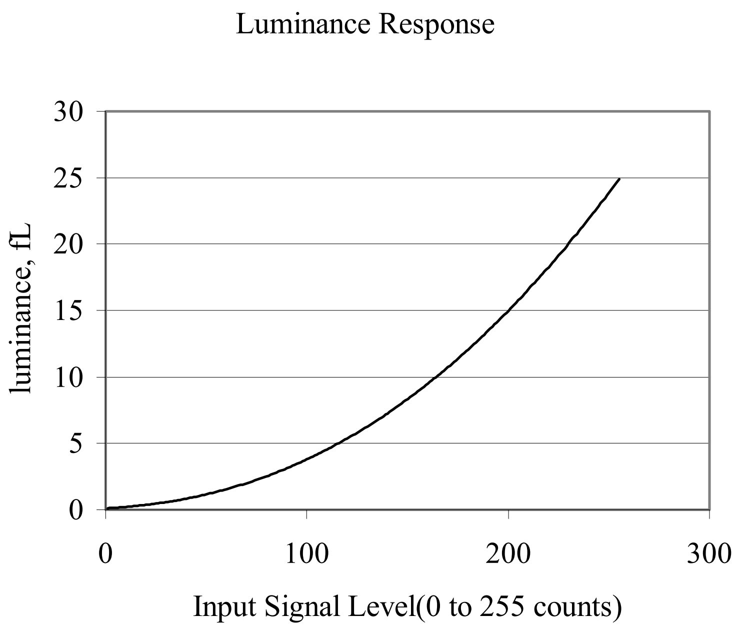


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

[3] Re-measurement of Lmax at screen center 9-19-2000 is 30.8 fL at 6500K when monitor timing optimized

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Back Ground	Target	L, fL	Diff, fL	Diff, JND
38	0	0.107	0	
39	1	0.116	0.009	2
39	2	0.125	0.009	2
39	3	0.135	0.01	3
40	4	0.144	0.009	2
40	5	0.154	0.01	2
41	6	0.165	0.011	2
41	7	0.176	0.011	2
41	8	0.187	0.011	2
42	9	0.198	0.011	2
42	10	0.212	0.014	3
42	11	0.225	0.013	2
43	12	0.238	0.013	2
43	13	0.252	0.014	2
43	14	0.268	0.016	3
44	15	0.283	0.015	2
44	16	0.301	0.018	2
44	17	0.318	0.017	3
45	18	0.335	0.017	2
45	19	0.351	0.016	2
45	20	0.368	0.017	2
46	21	0.386	0.018	2
46	22	0.406	0.02	2
46	23	0.423	0.017	2
47	24	0.443	0.02	3
47	25	0.462	0.019	2
48	26	0.484	0.022	2
48	27	0.507	0.023	2
48	28	0.524	0.017	2
49	29	0.548	0.024	2
49	30	0.572	0.024	2
49	31	0.595	0.023	3
50	32	0.619	0.024	2
50	33	0.644	0.025	2
50	34	0.671	0.027	2
51	35	0.698	0.027	2
51	36	0.723	0.025	2
51	37	0.747	0.024	2
52	38	0.774	0.027	2
52	39	0.802	0.028	2
52	40	0.831	0.029	3
53	41	0.863	0.032	2
53	42	0.893	0.03	2
53	43	0.924	0.031	2
54	44	0.952	0.028	2
54	45	0.985	0.033	2
55	46	1.018	0.033	2
55	47	1.052	0.034	2
55	48	1.091	0.039	3
56	49	1.124	0.033	2
56	50	1.161	0.037	2
56	51	1.196	0.035	2
57	52	1.233	0.037	2
57	53	1.271	0.038	2
57	54	1.305	0.034	2
58	55	1.346	0.041	2
58	56	1.385	0.039	2
58	57	1.424	0.039	2
59	58	1.463	0.039	2
59	59	1.508	0.045	2
59	60	1.546	0.038	2
60	61	1.592	0.046	2
60	62	1.629	0.037	2
60	63	1.675	0.046	2

Back Ground	Target	L, fL	Diff, fL	Diff, JND
61	64	1.721	0.046	2
61	65	1.764	0.043	2
62	66	1.811	0.047	2
62	67	1.858	0.047	2
62	68	1.903	0.045	2
63	69	1.952	0.049	2
63	70	1.998	0.046	2
63	71	2.047	0.049	2
64	72	2.094	0.047	1
64	73	2.142	0.048	2
64	74	2.198	0.056	2
65	75	2.253	0.055	2
65	76	2.306	0.053	2
65	77	2.354	0.048	2
66	78	2.406	0.052	2
66	79	2.467	0.061	2
66	80	2.528	0.061	2
67	81	2.579	0.051	2
67	82	2.647	0.068	2
67	83	2.702	0.055	2
68	84	2.757	0.055	1
68	85	2.814	0.057	2
69	86	2.879	0.065	2
69	87	2.933	0.054	2
69	88	2.997	0.064	2
70	89	3.062	0.065	2
70	90	3.127	0.065	1
70	91	3.193	0.066	2
71	92	3.254	0.061	2
71	93	3.316	0.062	2
71	94	3.389	0.073	2
72	95	3.453	0.064	1
72	96	3.525	0.072	2
72	97	3.587	0.062	2
73	98	3.663	0.076	2
73	99	3.733	0.07	2
73	100	3.797	0.064	1
74	101	3.868	0.071	2
74	102	3.943	0.075	2
74	103	4.016	0.073	2
75	104	4.086	0.07	1
75	105	4.162	0.076	2
76	106	4.244	0.082	2
76	107	4.314	0.07	2
76	108	4.387	0.073	1
77	109	4.465	0.078	2
77	110	4.542	0.077	2
77	111	4.617	0.075	1
78	112	4.699	0.082	2
78	113	4.784	0.085	2
78	114	4.874	0.09	2
79	115	4.947	0.073	1
79	116	5.036	0.089	2
79	117	5.108	0.072	1
80	118	5.202	0.094	2
80	119	5.286	0.084	2
80	120	5.362	0.076	1
81	121	5.458	0.096	2
81	122	5.545	0.087	2
81	123	5.633	0.088	1
82	124	5.712	0.079	2
82	125	5.811	0.099	2
83	126	5.899	0.088	1
83	127	5.985	0.086	2

Table II.6-2. System Tonal Transfer at center screen as a function of input counts
Target levels 128 to 255.

Back ground	Target	L, fL	Diff, fL	Diff, JND
83	128	6.071	0.086	1
84	129	6.167	0.096	2
84	130	6.278	0.111	2
84	131	6.377	0.099	1
85	132	6.468	0.091	2
85	133	6.566	0.098	1
85	134	6.669	0.103	2
86	135	6.754	0.085	1
86	136	6.847	0.093	2
86	137	6.964	0.117	2
87	138	7.051	0.087	1
87	139	7.165	0.114	2
87	140	7.252	0.087	1
88	141	7.361	0.109	2
88	142	7.472	0.111	1
88	143	7.559	0.087	2
89	144	7.705	0.146	2
89	145	7.804	0.099	1
90	146	7.912	0.108	2
90	147	8.029	0.117	1
90	148	8.129	0.1	2
91	149	8.251	0.122	1
91	150	8.348	0.097	2
91	151	8.476	0.128	1
92	152	8.572	0.096	2
92	153	8.692	0.12	1
92	154	8.785	0.093	1
93	155	8.922	0.137	2
93	156	9.012	0.09	1
93	157	9.156	0.144	2
94	158	9.276	0.12	1
94	159	9.389	0.113	2
94	160	9.497	0.108	1
95	161	9.643	0.146	2
95	162	9.742	0.099	1
95	163	9.874	0.132	2
96	164	9.994	0.12	1
96	165	10.13	0.136	2
97	166	10.23	0.1	1
97	167	10.37	0.14	1
97	168	10.48	0.11	2
98	169	10.63	0.15	1
98	170	10.74	0.11	1
98	171	10.87	0.13	2
99	172	10.98	0.11	1
99	173	11.12	0.14	1
99	174	11.26	0.14	2
100	175	11.39	0.13	1
100	176	11.54	0.15	2
100	177	11.68	0.14	1
101	178	11.81	0.13	2
101	179	11.95	0.14	1
101	180	12.08	0.13	1
102	181	12.22	0.14	2
102	182	12.34	0.12	1
102	183	12.49	0.15	1
103	184	12.61	0.12	1
103	185	12.77	0.16	2
104	186	12.93	0.16	1
104	187	13.05	0.12	2
104	188	13.19	0.14	1
105	189	13.34	0.15	1
105	190	13.49	0.15	2
105	191	13.63	0.14	1

Back ground	Target	L, fL	Diff, fL	Diff, JND
106	192	13.79	0.16	1
106	193	13.97	0.18	2
106	194	14.09	0.12	1
107	195	14.22	0.13	1
107	196	14.37	0.15	1
107	197	14.52	0.15	2
108	198	14.66	0.14	1
108	199	14.82	0.16	1
108	200	14.97	0.15	1
109	201	15.14	0.17	2
109	202	15.29	0.15	1
109	203	15.45	0.16	1
110	204	15.59	0.14	1
110	205	15.76	0.17	2
111	206	15.94	0.18	1
111	207	16.08	0.14	1
111	208	16.27	0.19	2
112	209	16.41	0.14	1
112	210	16.58	0.17	1
112	211	16.77	0.19	1
113	212	16.93	0.16	2
113	213	17.08	0.15	1
113	214	17.25	0.17	1
114	215	17.43	0.18	1
114	216	17.59	0.16	1
114	217	17.73	0.14	1
115	218	17.93	0.2	2
115	219	18.11	0.18	1
115	220	18.24	0.13	1
116	221	18.44	0.2	1
116	222	18.62	0.18	2
116	223	18.78	0.16	1
117	224	18.95	0.17	1
117	225	19.13	0.18	1
118	226	19.31	0.18	1
118	227	19.49	0.18	1
118	228	19.64	0.15	1
119	229	19.83	0.19	2
119	230	20.07	0.24	1
119	231	20.25	0.18	1
120	232	20.43	0.18	1
120	233	20.61	0.18	2
120	234	20.74	0.13	0
121	235	20.97	0.23	2
121	236	21.16	0.19	1
121	237	21.33	0.17	1
122	238	21.52	0.19	1
122	239	21.69	0.17	1
122	240	21.91	0.22	1
123	241	22.12	0.21	2
123	242	22.31	0.19	1
123	243	22.49	0.18	1
124	244	22.69	0.2	1
124	245	22.85	0.16	1
125	246	23.08	0.23	1
125	247	23.26	0.18	1
125	248	23.46	0.2	1
126	249	23.66	0.2	1
126	250	23.87	0.21	2
126	251	24.08	0.21	1
127	252	24.27	0.19	1
127	253	24.47	0.2	1
127	254	24.66	0.19	1
128	255	24.87	0.21	1

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

No video artifacts were observed.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

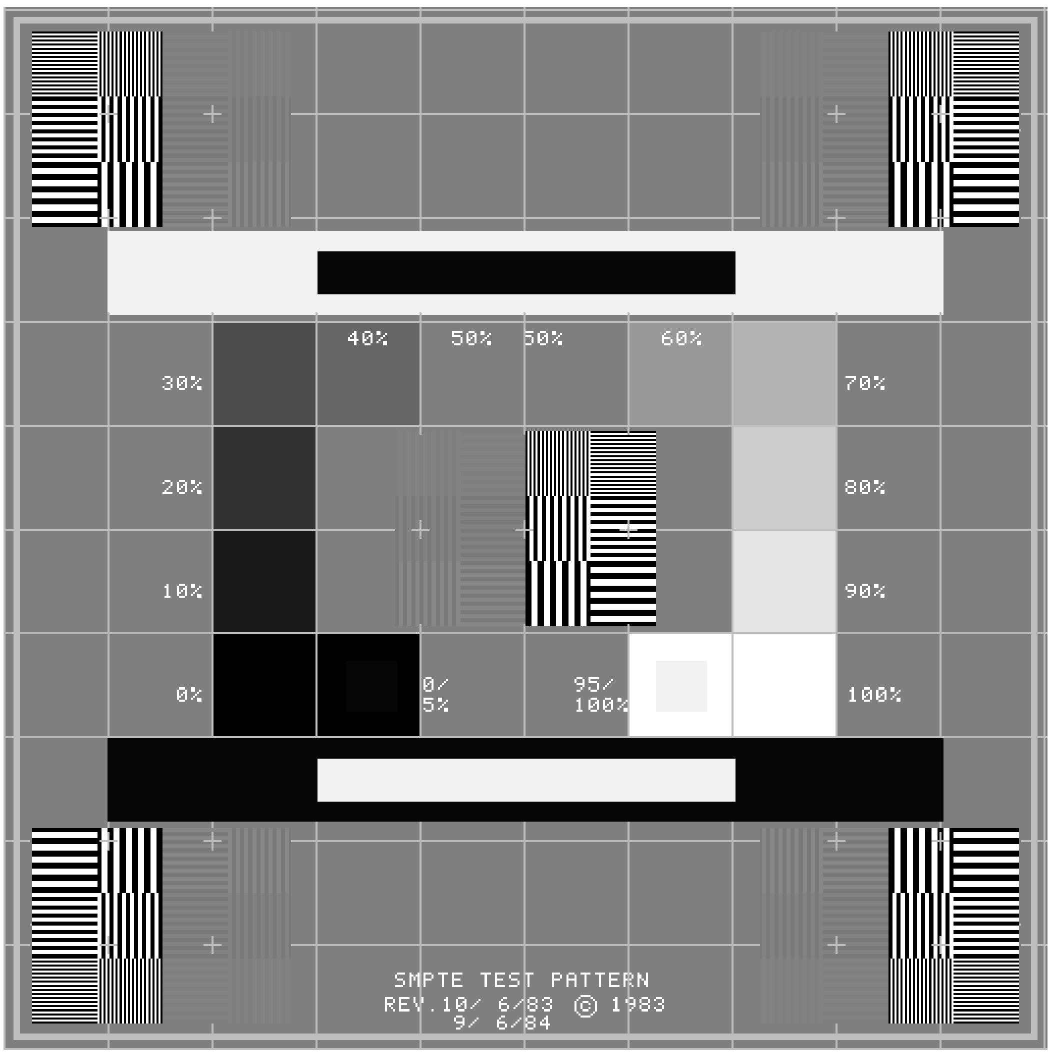


Figure II.8-1. SMPTE Test Pattern.

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the Siemens SCM21130LS monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested format (HxV):
1600 x 1200 x 73 Hz, 1024 x 1024(interlaced) x 121 Hz.

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 73 Hz minimum for monoscopic mode and 121 Hz minimum for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode
1600 x 1200	1024 x 1024

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is 1:1.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Mode
Addressability (H x V)	1600 x 1200
H x V Image Size (inches)	14.96 x 11.22
H x V Pixel Spacing (mils)	9.35 x 9.35
H x V Pixel Aspect Ratio	H = V + 0%

II.11. Screen Size (Viewable Active Image)

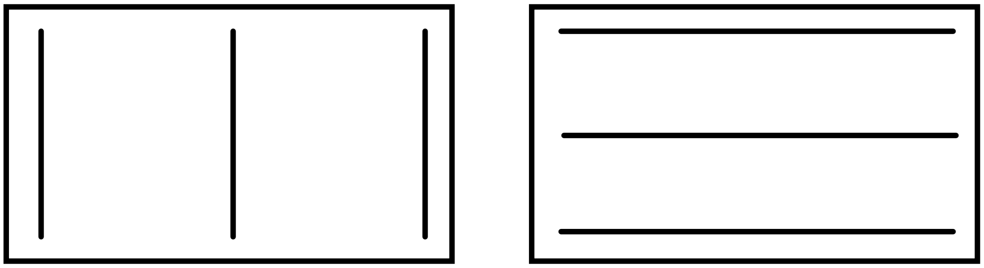
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size as tested in monoscopic mode (1600 x 1200) was 18.7 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x, y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Mode
Addressability (H x V)	1600 x 1200
H x V Image Size (inches) Diagonal Image Size (inches)	14.96 x 11.22 18.7

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 36% in Zone A 9.54 inch circle, and exceeded Cm = 21% in Zone B.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

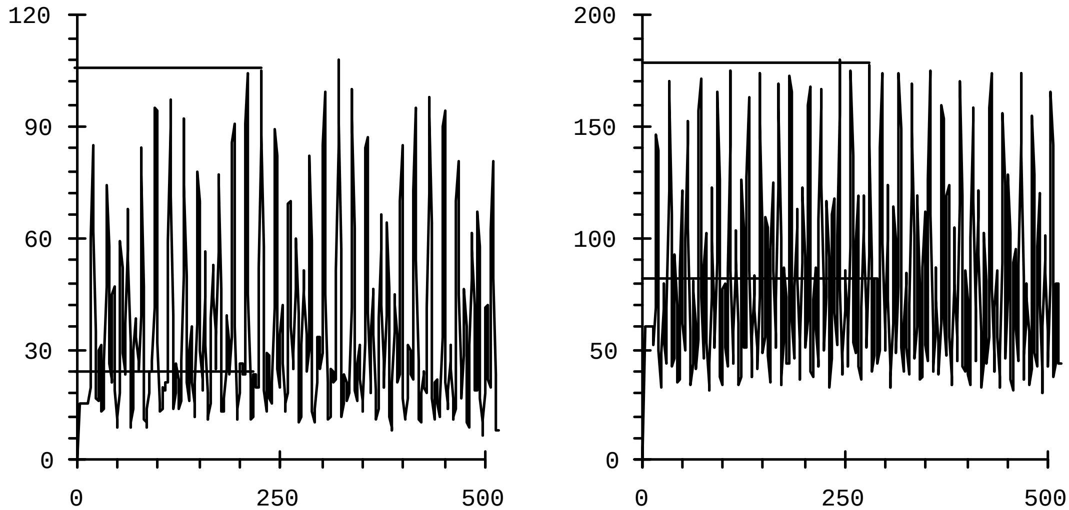
Procedure: The maximum video modulation frequency for each format (1600 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

Zone A is defined as a 24 degree subtended circle from a viewing distance of 18 inches (7.6 inch circle). Alternatively, Zone A is a 9.54 inch circle in the center of the viewing area. Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 36% in Zone A, and is equal to or greater than 21% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadow mask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

Table II.12-1. Contrast Modulation

Corrected for lens flare and Zone Interpolation

Zone A = 7.6-inch diameter circle for 24-degree subtended angle at 18-inch viewing distance

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	38%	33%			30%	52%			21%	27%
			53%	40%	41%	50%	46%	38%		
Major	58%	41%	60%	43%	63%	45%	43%	38%	23%	32%
			61%	41%	54%	46%	47%	39%		
Bottom	58%	35%			49%	47%			22%	32%

Zone A = 9.54-inch diameter circle for 40% area

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	38%	33%			30%	52%			21%	27%
			51%	39%	36%	51%	42%	36%		
Major	58%	41%	60%	43%	63%	45%	38%	37%	23%	32%
			60%	40%	51%	46%	43%	38%		
Bottom	58%	35%			49%	47%			22%	32%

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was 104 H x 104 V pixels per inch (ppi) as tested for the 1600 x 1200-line format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
H x V Addressability, Pixels	1600 x 1200
H x V Image Size, Inches H x V Pixel Density, ppi	14.96 x 11.22 107 x 107

II.14. Moiré

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Phosphor-to-pixel spacing ratios are less than 0.9 for the 1600 x 1200 format.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

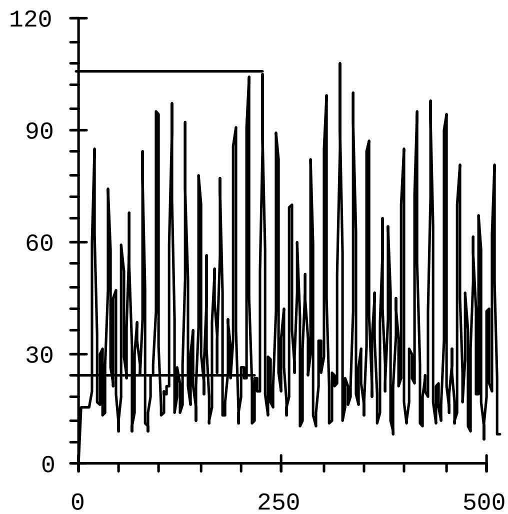
Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

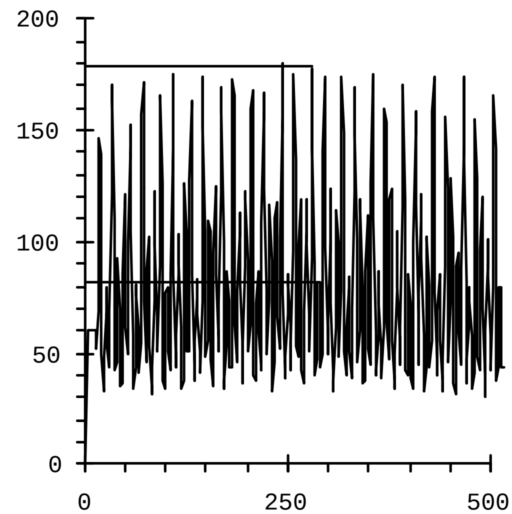
Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Mode
Addressability	1600 x 1200
Pixel Spacing (H x V	9.64 x 9.64 mils (0.245 mm x 0.245 mm)
Phosphor Pitch (H x V)	0.22 mm x 0.14 mm (measured)
Phosphor-to-Pixel-Spacing	0.90 H x 0.57 V

Discussion: Moiré occurs when the phosphor pitch is too large in comparison to the pixel size. Studies have shown that a phosphor pitch of <1 pixel is required for adequate visibility of image information without interference from the phosphor structure.



Monitor A
0.28mm dot pitch



Monitor B
0.26mm dot pitch

Figure II.12-1. *Contrast modulation for sample luminance profiles (1pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.*

In Figure II.12-1, Monitor A phosphor pitch is 0.90 pixels as compared with 0.84 pixels in Monitor B. Moiré is more visible in Monitor A, appearing as long stripes where contrast modulation has been degraded. In Monitor B, moiré is less visible, appearing as "fish-scales" where contrast modulation has been reduced. Even though the Monitor A exhibits a greater loss of contrast modulation from the presence of moiré on 1-on/1-off vertical grille patterns, there is little or no visual impact when aerial photographic images are displayed. NIDL experts in human vision and psychophysics were unable to discern presence of moiré on either monitor when grayscale imagery was displayed.

II.15. Straightness

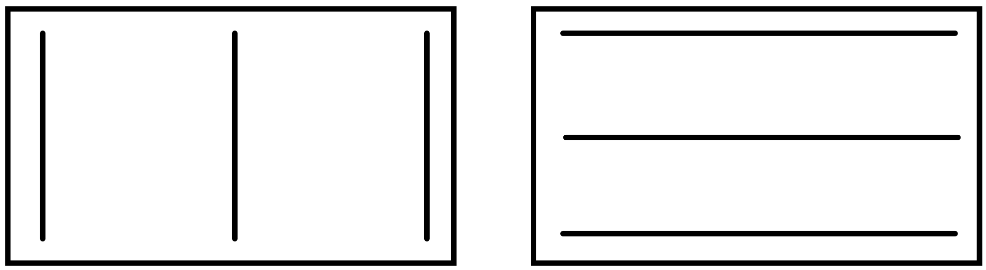
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Deviation from straightness did not exceed 0.42% of the total image height or width.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

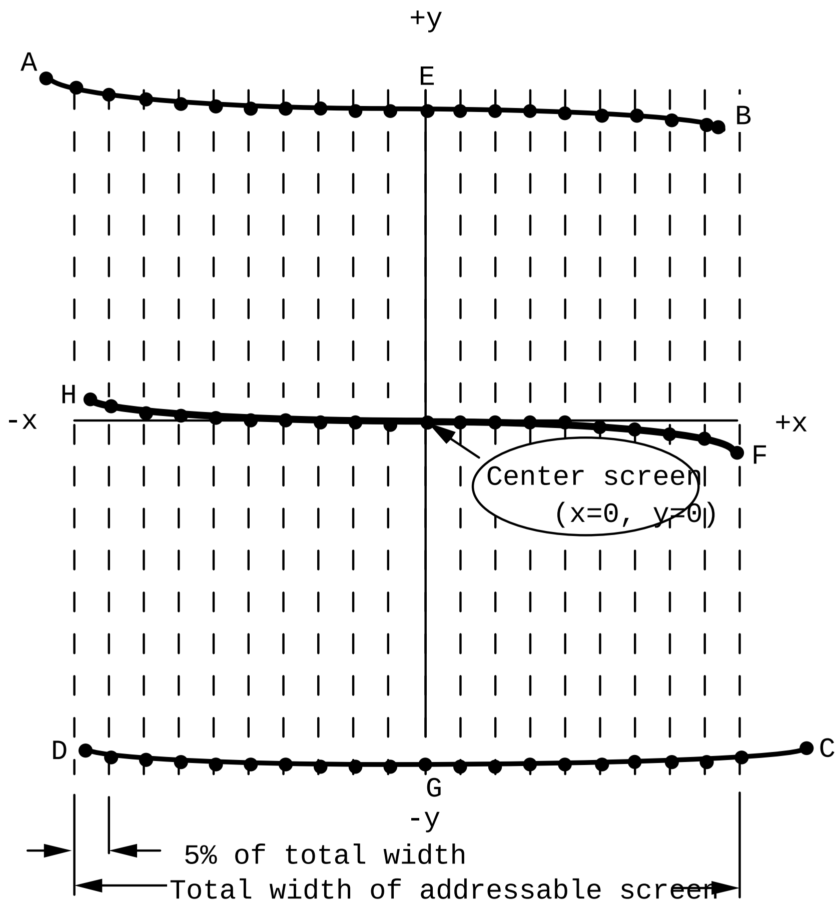


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x, y coordinates along the length of a nominally straight line. Measure x, y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x, y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness

Tabulated x, y positions at 5% addressable screen increments along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7707	5715	-7711	-5758	-7748	6	22	5681	-7707	5714	7693	5674
-7200	5715	-7200	-5762	-7200	6	22	5400	-7711	5400	7696	5400
-6400	5714	-6400	-5760	-6400	6	20	5400	-7721	4800	7703	4800
-5600	5709	-5600	-5754	-5600	5	17	4800	-7730	4200	7709	4200
-4800	5705	-4800	-5749	-4800	4	12	4200	-7739	3600	7712	3600
-4000	5702	-4000	-5744	-4000	4	9	3600	-7746	3000	7715	3000
-3200	5699	-3200	-5737	-3200	3	6	3000	-7750	2400	7718	2400
-2400	5695	-2400	-5732	-2400	2	4	2400	-7754	1800	7719	1800
-1600	5691	-1600	-5727	-1600	1	1	1800	-7754	1200	7719	1200
-800	5687	-800	-5723	-800	0	0	1200	-7753	600	7718	600
0	5683	0	-5720	0	0	0	600	-7751	0	7714	0
800	5680	800	-5720	800	-1	0	0	-7748	-600	7711	-600
1600	5680	1600	-5721	1600	-2	0	-600	-7747	-1200	7707	-1200
2400	5680	2400	-5727	2400	-4	0	-1200	-7745	-1800	7704	-1800
3200	5680	3200	-5732	3200	-6	0	-1800	-7742	-2400	7701	-2400
4000	5680	4000	-5739	4000	-7	0	-2400	-7739	-3000	7695	-3000
4800	5680	4800	-5747	4800	-8	1	-3000	-7732	-3600	7688	-3600
5600	5681	5600	-5755	5600	-10	2	-3600	-7727	-4200	7677	-4200
6400	5682	6400	-5762	6400	-12	2	-4200	-7722	-4800	7668	-4800
7200	5680	7200	-5765	7200	-15	2	-4800	-7716	-5400	7662	-5400
7693	5676	7654	-5765	7714	-16	3	-5400	-7712	-5758	7656	-5765

1600 x 1200

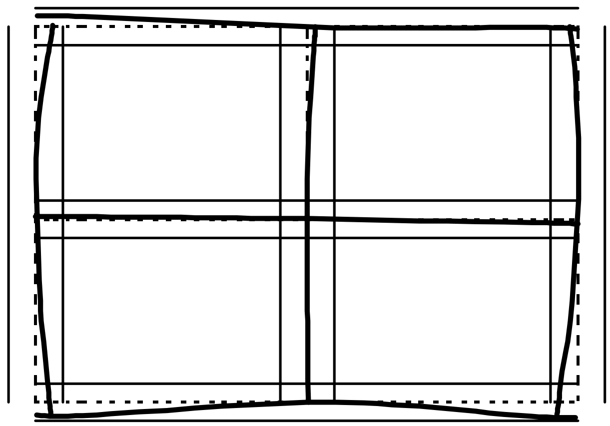


Figure II.15-3 Waviness of Siemens SCM21130LS Color monitor in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for 1600 x 1200 format was set to 73 Hz. Vertical refresh rate for the 1024 x 1024 stereo format was set to 121 Hz (60.5 Hz per eye).

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	Stereo Mode
Addressability	1600 x 1200	1024 x 1024
Vertical Scan	73.011 Hz	121.03 Hz
Horizontal Scan	91.118 kHz	130.288 kHz

II.17. Extinction Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio was averaged to 11.2:1 (11.3 left, 11.1 right)[4] *at screen center. Luminance of white varied by up to 20.5% across the screen. Chromaticity variations of white were less than 0.008 Δu'v' units.*

Objective: Measure stereo extinction ratio

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially-available StereoGraphics 19-inch LCD shutter with passive polarized eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

[4] Re-measurement of stereo extinction ratio at screen center 9-19-2000 when monitor timing optimized

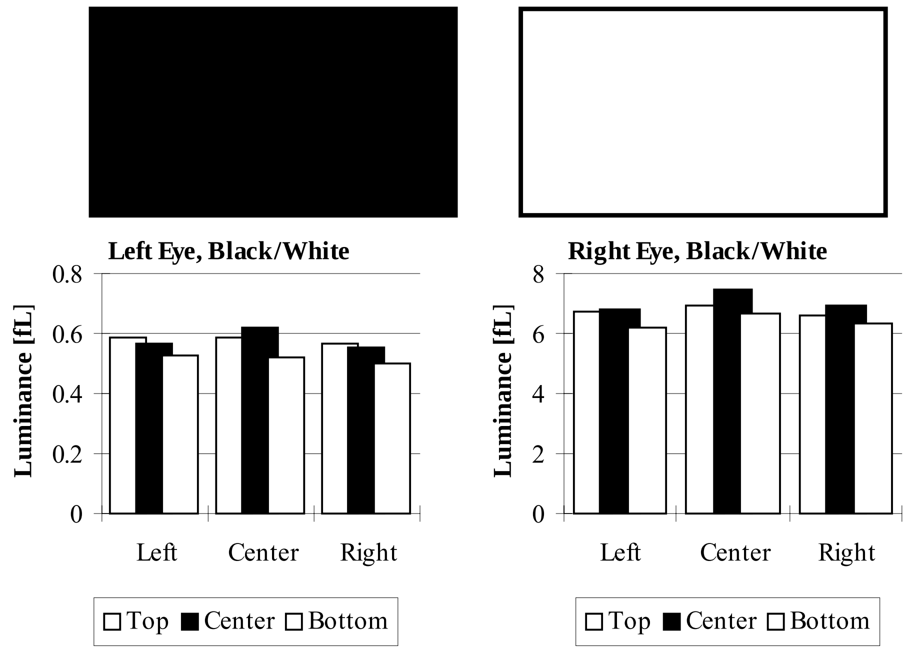


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

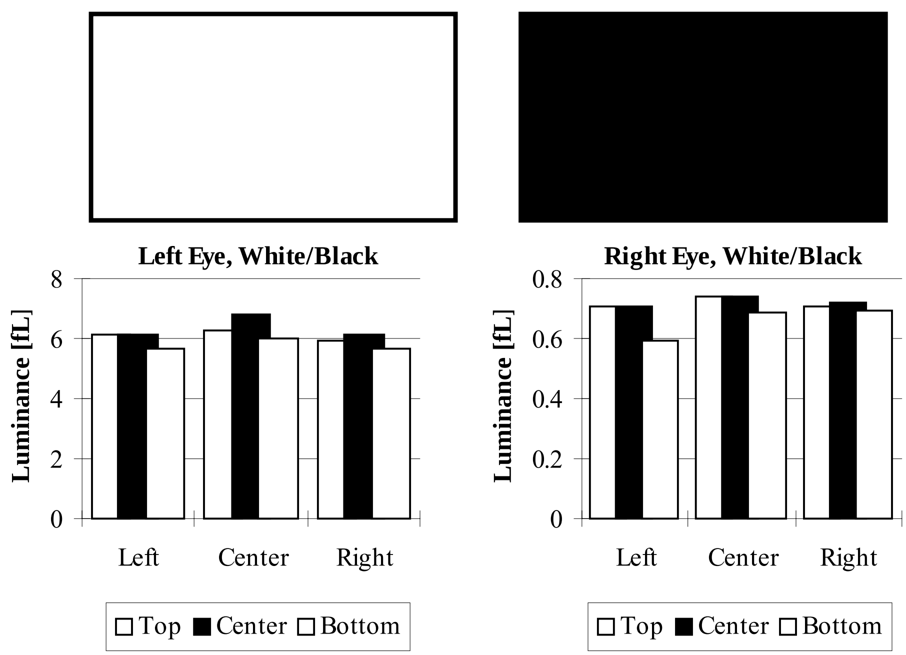


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

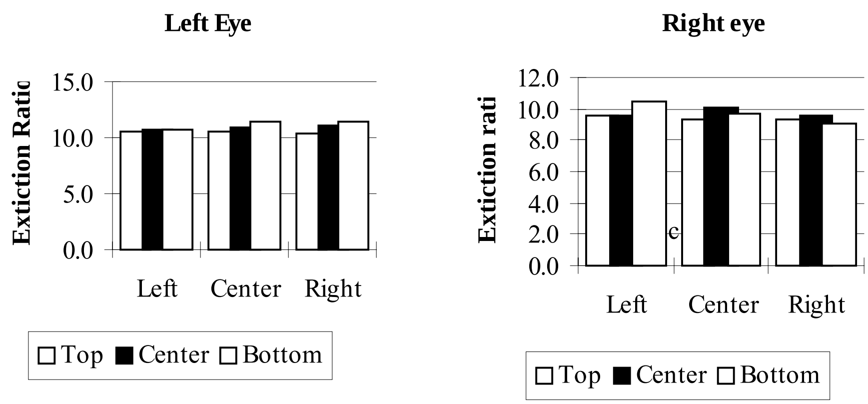


Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

Fig.II.17-4 Spatial uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 1.59 % .

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

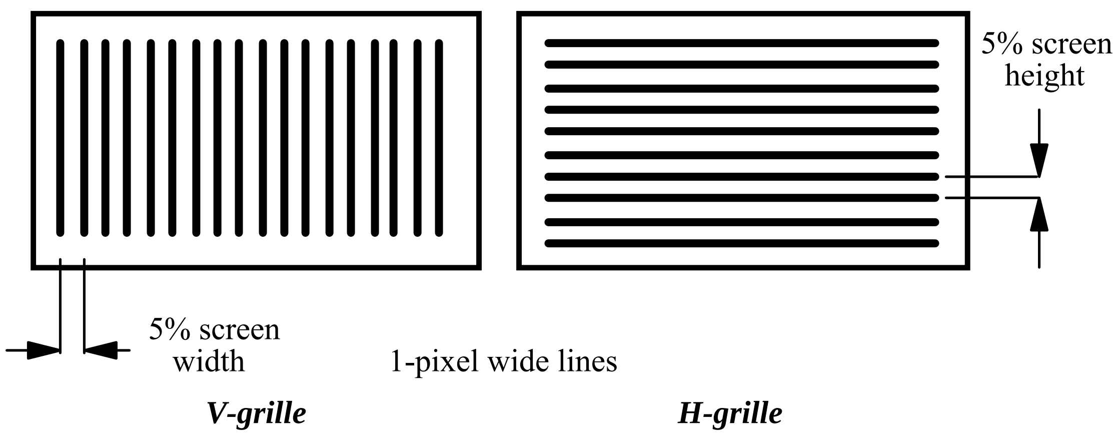


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x, y-translation stage to measure screen x, y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

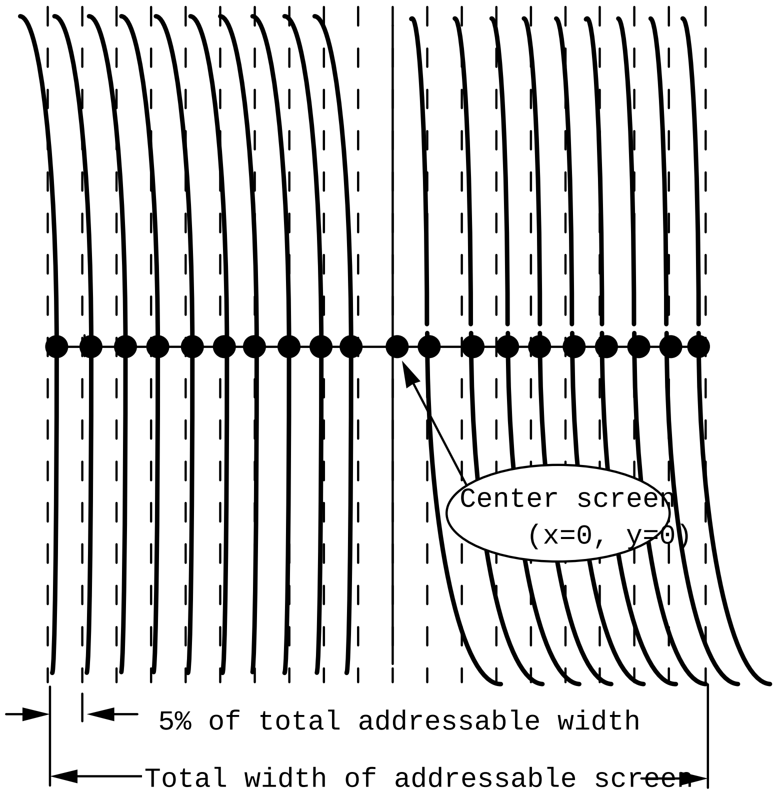


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

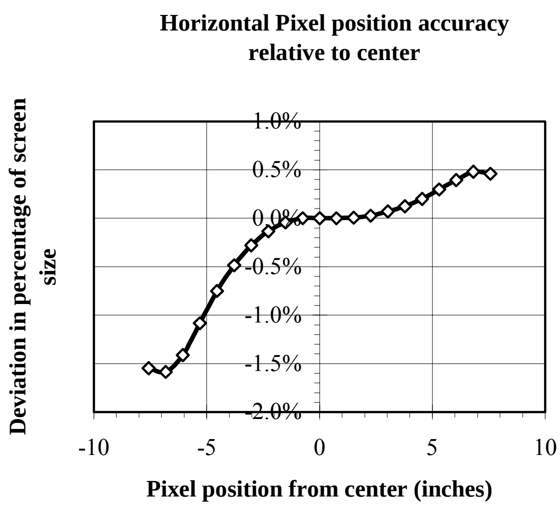
Data: Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impacts the absolute position of each pixel on the screen and is, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figure II.18-3.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities between equal spacings

Format	Left Side	Right Side	Top	Bottom
1600 x 1200	1.59%	0.48%	0.12%	0.75%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	Right Side	Top	Bottom
-7809	7641	5604	-5674
-7058	6887	5049	-5120
-6274	6117	4489	-4555
-5466	5345	3929	-3983
-4658	4573	3365	-3409
-3860	3804	2801	-2835
-3071	3039	2239	-2260
-2292	2275	1679	-1688
-1521	1515	1119	-1120
-757	757	559	-560
0	0	0	0



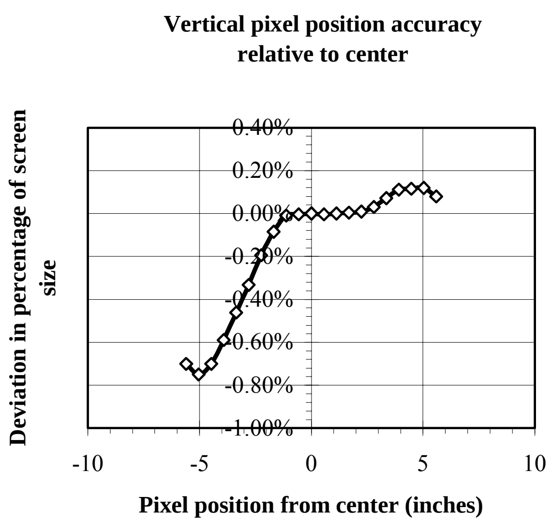


Fig. II.18-5 Horizontal and vertical linearity characteristics.

II.19. Jitter/Swim/Drift

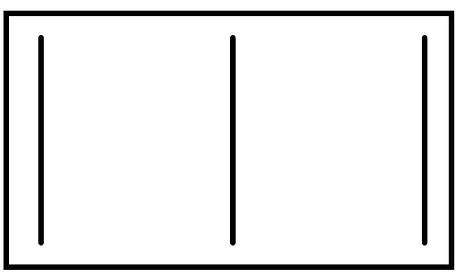
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter, swim, and drift were 1.35 mils, 1.42 mils and 1.46 mils, respectively.

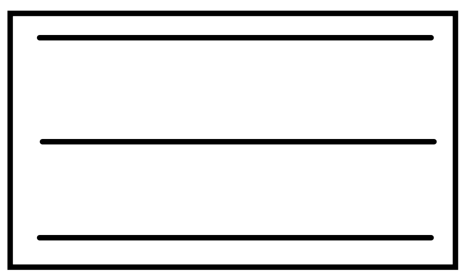
Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depend upon the amplitude and frequency of the motions which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion



H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.

Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

1600 x 1200 x 73 Hz

Signal Generator			**Quantum Data FOX 8701**	
Position			H-lines	V-lines
10D corner	Max Motions			
		Jitter	1.35	1.02
		Swim	1.42	1.15
		Drift	1.46	1.15

II.20 Warm-up Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 60-minute warm-up was necessary for luminance stability of Lmin = 0.1 fL +/- 10%.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1600 x 1200 format in graphical form. The luminance remains very stable after 60 minutes.

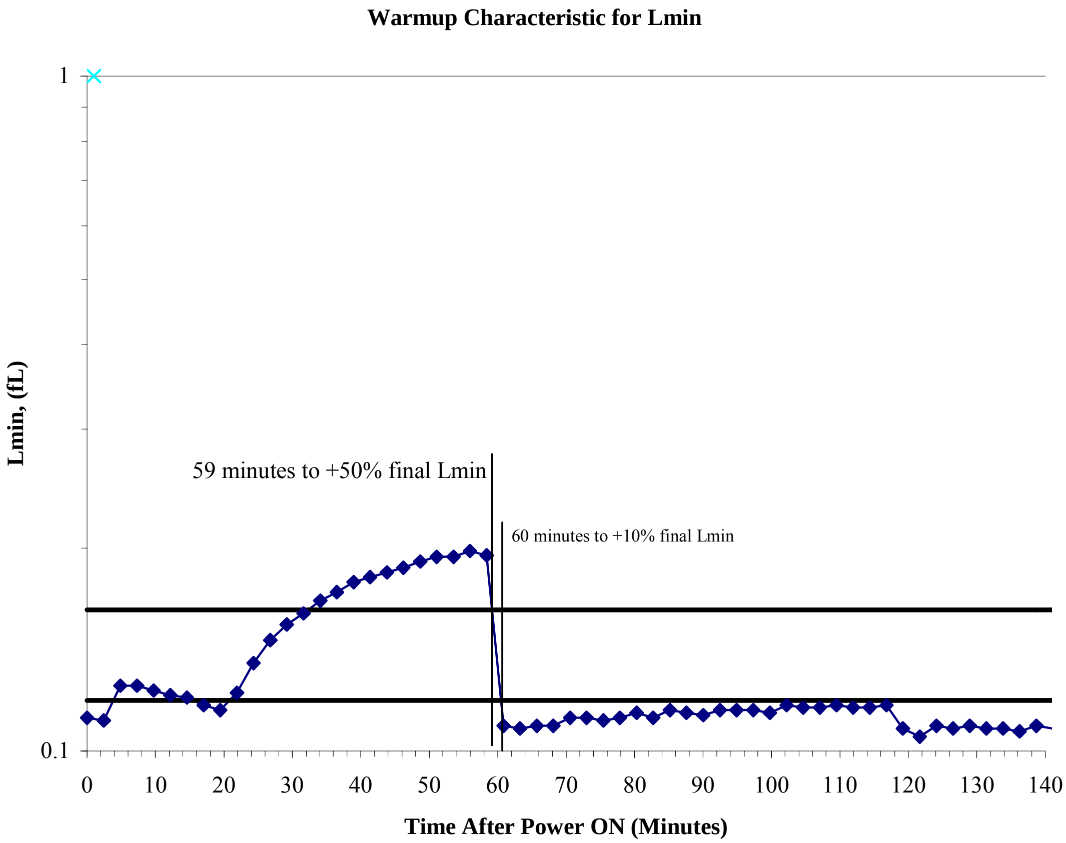


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).

By way of explanation of the above warm-up behavior, the manufacturer[5] stated that the luminance, Lmin, in a CRT-monitor can increase during warm-up, due to natural thermal stabilization effects inside the tube. This is a normal effect in every CRT. To control this effect, Siemens has a built-in stabilization circuit to compensate for these drift effects in the monitors. In the color monitor, the current for each gun (R/G/B) is measured and adjusted. This circuit is mainly designed to keep the luminance levels and color temperature settings stabilized over the lifetime of the monitor, as well as during warm-up. This unique circuit was originally designed for the grayscale monitors, and the stability requirements of these products. Siemens has kept this active in its color monitor, to be able to have a color product that also meets these high demands. The results of this is a product which will have very stable luminance settings and color temperature, over its lifetime.

---

[5] George Scott, Technical Marketing & Product Support Manager, Siemens Display Technologies 9-25-2000

The stabilization procedure in the Siemens color monitors works as follows: During the first 20 minutes, the stabilization circuit activates every minute. After this period, the circuit activates at the 1hr point, and every hour thereafter. During each activation cycle, the currents are adjusted. NIDL testing reflects this cycle. From the NIDL graph II-20.1, the Lmin level is controlled over the first 20 minutes, and continues to decrease closer to the set point. And at the 60 minute point we see a sharp reduction down to the expected level, and again at the 120 minute point. What is not taken into account is continuation of the thermal stabilization occurring between the 20 and 60 minute time frames.

To meet the higher warm-up requirements of the IEC specification, it is possible for Siemens to modify the firmware so that during the warm-up time, the currents of each cathode are measured and adjusted more often, e.g. every minute during the first 60 minutes, and then move to a once-an-hour measurement. This will remove the rise that is occurring between 20 and 60 minutes, and thereby meet the specification.

In order to accomplish this change, Siemens software engineers will update the monitor firmware that implements this new warm-up routine. This new firmware has been demonstrated now for a companion color monitor and has eliminated the initial ramp-up in luminance. Siemens will send to NIDL new firmware, along with an easy procedure to update the test monitor. The firmware IC is accessible by dropping down the keypad tray, and removing one shield - the rear cover does not have to be removed.